equipment has been calibrated and multiple testing has shown the same result, these students should be trying to identify other factors which might cause an increase.

Section 1 - pH and Temperature Data

Part 1 - Identifying Outliers

1. Show students the graphs in Figures HYD-L-2 and HYD-L-3. After they have had an opportunity to examine the graphs and record their observations, ask them to identify any unusual data points.
2. Discuss the importance of data quality. Ask students what they should do if some data points are far beyond the range of the rest of the set (are they outliers)?
3. Discuss their observations and recommendations.

Note from the scientists

We have plotted all of the data as time series graphs. Before we can discern trends and compare data from different sites, we go through the data carefully looking for outliers. For example, notice in Figure HYD-L-2 that one temperature reading lies outside the range of the others. This is probably an error, and we will remove this point from our analysis before continuing.

In addition, pH readings that deviate significantly from the average are suspect. For Figure HYD-L-3, note the single pH 4 reading, with the rest of the pH's being in the 6-9.5 range.

Some additional items of interest can be seen looking at these graphs. Figure HYD-L-3 shows what appears to be a pH trend gradually climbing over the course of the record. The pH's seem to be more scattered than would be expected. Why do you suppose this is the case? In Figure HYD-L-2, we see a more typical variation in pH values, with a gradually increasing trend. This might be a problem associated with a buffer solution that was losing its accuracy, or it might actually represent a real pattern in nature!

Further Analysis

Encourage students to look at their own data. Time series graphs may be generated by importing GLOBE data into a spreadsheet, or by using the new GLOBE graphing tools to graph student data.

Figure HYD-L-2: GLOBE School in California, USA

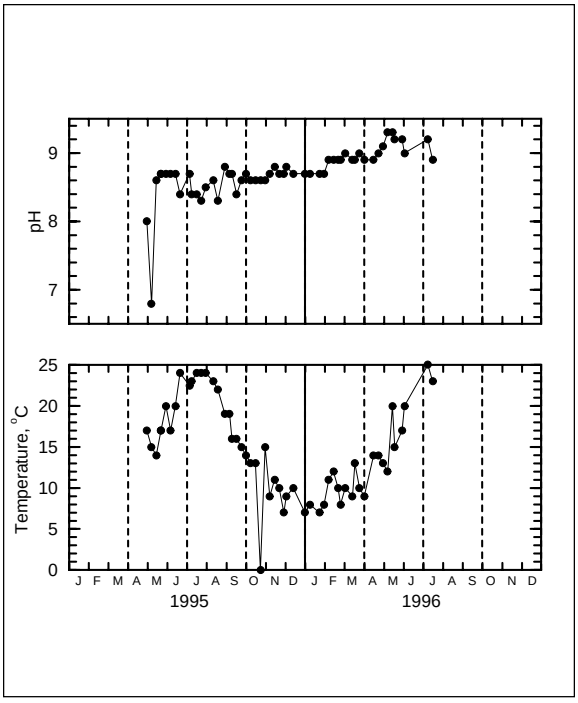
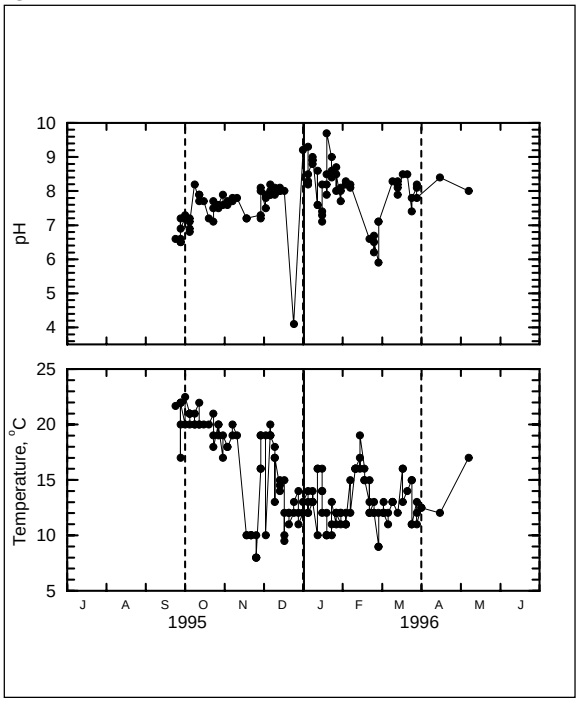


Figure HYD-L-3: GLOBE School in California, USA



The graphing tools can be accessed at the GLOBE visualization location on the GLOBE Student Server. Instructions for accessing the graphing capabilities are available in the Toolkit. Have students try to locate outliers in their own data to minimize the possibility that calibration error or measurement inconsistencies may be influencing data.

You may also use GLOBE visualizations to try to identify daily observations that may be unusual. See Figure HYD-L-6. Students should generate point and contour maps of the weekly observations to try to identify unusual patterns; for example, a light blue point (very low temperature) within an area of orange and red points (warm temperatures). If students find questionable data, they may then locate the data set for that site and try to identify reasons for the anomaly or contact the site using GLOBEMail to ask questions about the data.

Part 2 - Investigating the Range of pH Values

My pH values are jumping around unpredictably.

Figure HYD-L-4: GLOBE School In Florida, USA

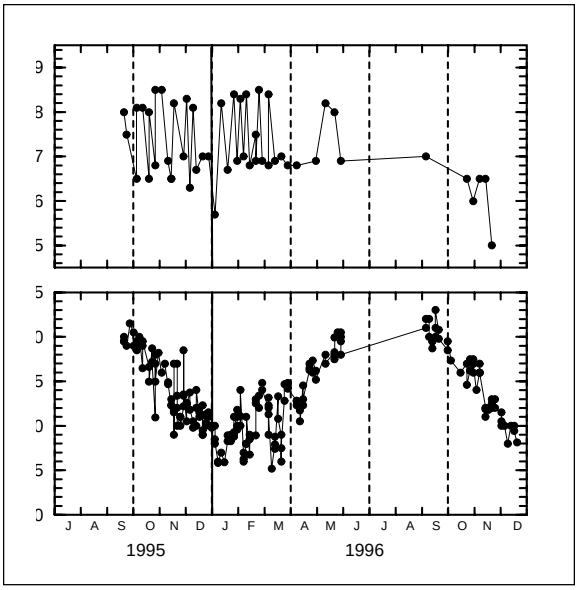
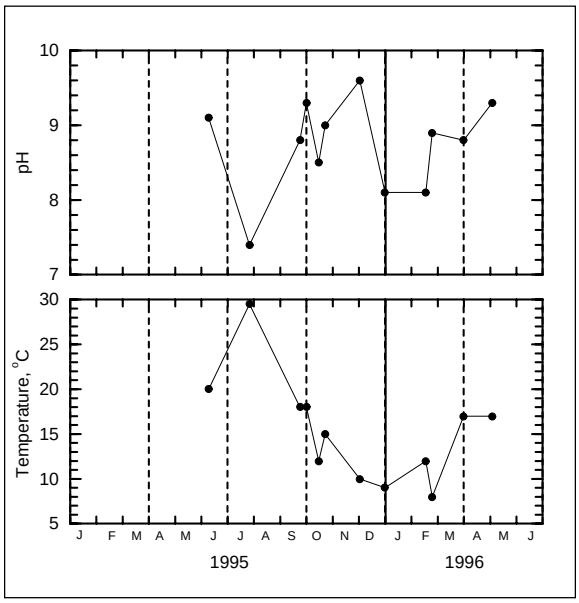


Figure HYD-L-5: GLOBE School in Washington, USA



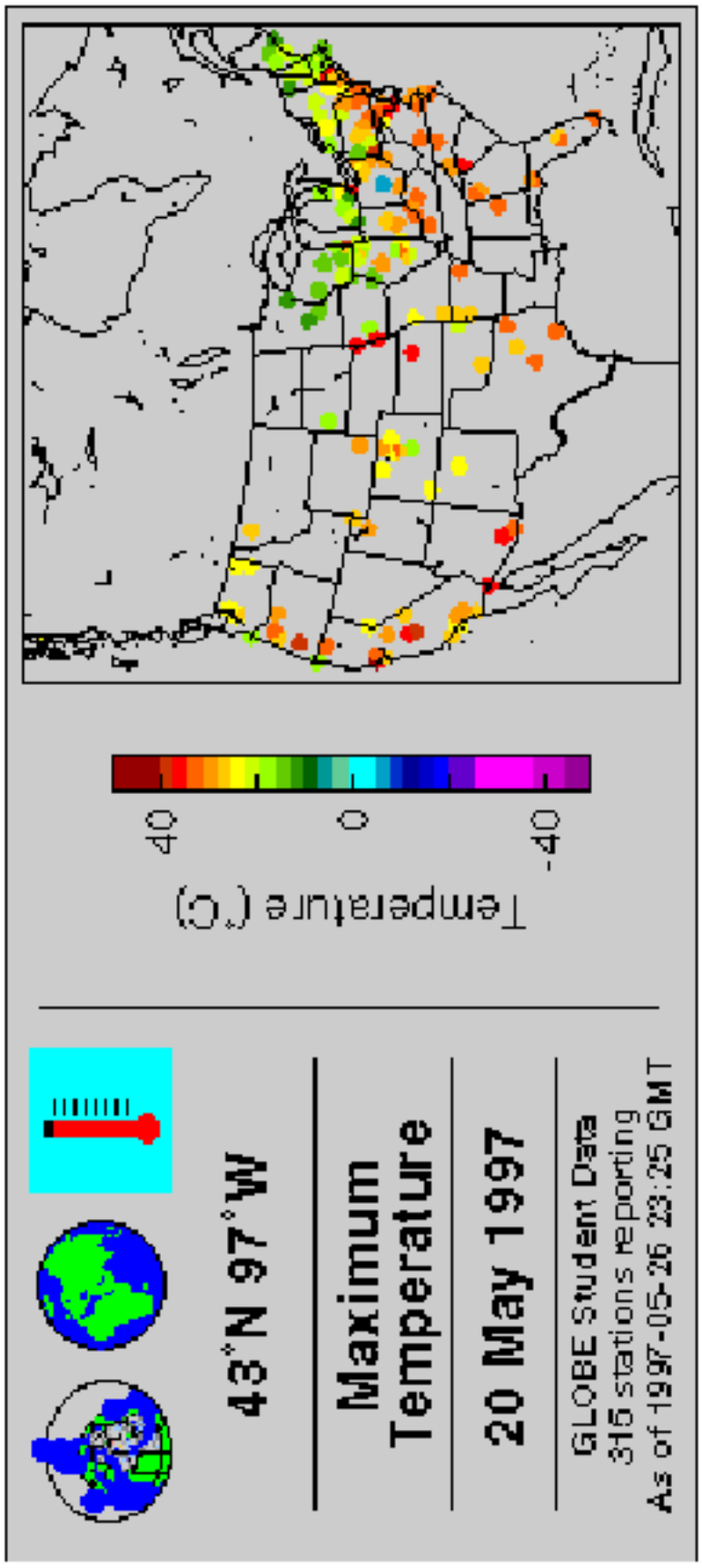
Is this right? Should my pHs be this jumpy?

1. Show students the 2 sets of graphs in Figures HYD-L-4 and HYD-L-5. After they have had an opportunity to examine the graphs and record their observations, ask them to identify any unusual trends.
2. Discuss the range of pH that the students have been finding at their own site. How much variation in pH readings have they found?
3. Have students use the GLOBE graphing tools to graph their own pH data and that of a few other schools. What is the range of their data?
4. Discuss their observations and recommendations.

Note from the scientists

These graphs in Figures HYD-L-4 and HYD-L-5 are good examples of curious pH readings in data sets. Here the pH values seem to be bouncing back and forth over a range of almost 3 pH units. What do you think might be going on in this case? Keep in mind that pH's are usually fairly steady measurements unless there is a major disturbance to a stream or lake such as periodic waste discharge, a very large rainfall, a large algae bloom, or a change in flow rate due to upstream snowmelt. A good example of a periodic change in water flow might also be the discharge from a reservoir upstream. This would significantly affect

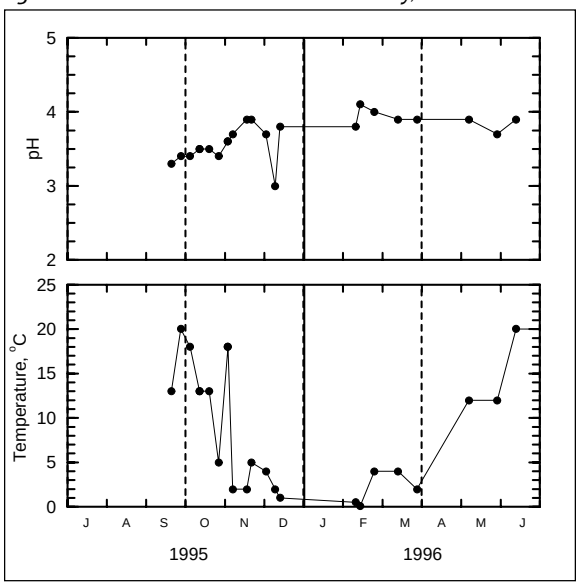
Figure HYD-L-6: Temperature from GLOBE Student Data Server



pH values measured downstream. This set of temperature data shows nice, predictable seasonal trends. Are there major disturbances going on, or do these data merely reflect part of the learning process?

I wonder why we're finding such low pH values?

Figure HYD-L-7: GLOBE School in New Jersey, USA



1. Show students the set of graphs in Figure HYD-L-7. After they have had an opportunity to examine the graphs and record their observations, ask them to identify any unusual trends. Would they expect pH readings to be this low? Have them explain why or why not. They should justify their explanation using the data and background information about pH.
2. Ask students to form a hypothesis on why the pH results are so low for this site.
3. Ask them how they could test their hypotheses.
4. Identify other sites from the GLOBE Student Server in the same area. Retrieve the data for these sites and compare them to this site.

Note from the scientists

This graph in Figure HYD-L-7 is an excellent example of a hydrology site exhibiting low pH readings. The question is how likely is it that the pH of the water is really this low? This graph shows a pH data range of about 3 to about 4.5. Natural waters tend to be in the pH range of 6 to 8.

Possibilities

- This is real! If you think this is the case, then the next step is to ask yourselves and your classmates why the pH is so low. What does this say about the path the water has followed to reach this Hydrology Study Site?
- This is a product of how you did your tests. Unfortunately, although we all try our best to make sure our data are accurate, sometimes there is one step we missed which is causing an error in our data. Other times, the materials we have to work with are not in good shape. In the case of low pH values, it seems most likely that the solutions that the school is using for calibration are no longer good. Certainly testing these standards is a good place to start.

Testing your Standard Solutions

To investigate the possibility that your Standard Solutions are not good, you have a couple of choices:

- Buy a new set of standard solutions and compare them to your old ones.
- Calibrate your pH meter with your solutions, then use it to test the pH of a freshly opened soft drink. These products, due to their production standards, are consistently the same pH and can be used as a comparison to see if your pH meters are measuring correctly.

Below is a set of pH's for several soft drinks at room temperature:

Coca-Cola 2.5
RC-cola 2.5
Mr. Pibb 2.8
Pepsi-Cola 2.5
Sprite 3.2

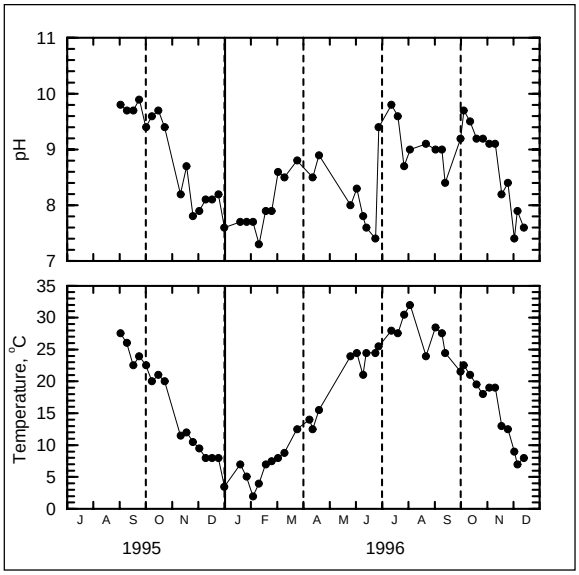
Further Investigations

Have students test their own instruments using the information above.

Part 3 - Identifying pH and Temperature Patterns

This is neat! My pH values and temperatures are going up and down smoothly!

Figure HYD-L-8: GLOBE School in Japan



1. Show students the set of graphs in Figure HYD-L-8. After they have had an opportunity to examine the graphs and record their observations, ask them to identify any unusual trends.
2. Ask students to form a hypothesis on why the temperature graph would show the pattern it does. Does pH normally follow temperature this closely?
3. Graph your own data and data from other sites, especially Japan, using the GLOBE graphing tools, to compare the data with these graphs.

Note from the scientists

Sometimes everything you're doing seems to be right, and you notice what seems to be a really neat trend to your data! As a contributor to the scientific body of knowledge, it is important to look at your data and keep checking to see if you are being accurate. In Figure HYD-L-8 showing data from a GLOBE school in Japan, we see what looks like a consistent and smooth trend in pH. It seems to follow the temperature to a remarkable degree, and even seems to be within a more or less acceptable range.

The data look good! Why the concern?

The data look good because there do not appear to be any major jumps in the measurements, the data are consistently being entered, and the temperature measurements show a smooth and predictable trend. However look at the next couple of observations...

- It is quite unusual for natural processes to change pH by more than 1 or 1.5 units. Also pH values above pH 9.0 are not that common in lakes and streams.
  It would be interesting to see if other schools in the same area show the same trends.
- Although temperature and pH are related to some degree, we would not expect such strong correlation as a result. The pH meters should also be designed to automatically correct for temperature. Was that true in this case?

Part 4 - How will pH Paper and pH Meters Differ?

What was used to take these pH measurements: a pH meter or pH paper?

1. Explain that students in different schools may be using pH paper, pH pens and pH meters to collect pH data.
2. Show students the sets of graphs in Figures HYD-L-9 and HYD-L-10. After they have had an opportunity to examine the graphs and record their observations, ask them to form a hypothesis on what instrumentation was used to take the pH measurements.
3. Ask students how they can justify or support their hypotheses regarding the instrumentation used in collecting the pH data.

Figure HYD-L-9: GLOBE School in the Midwest of the United States

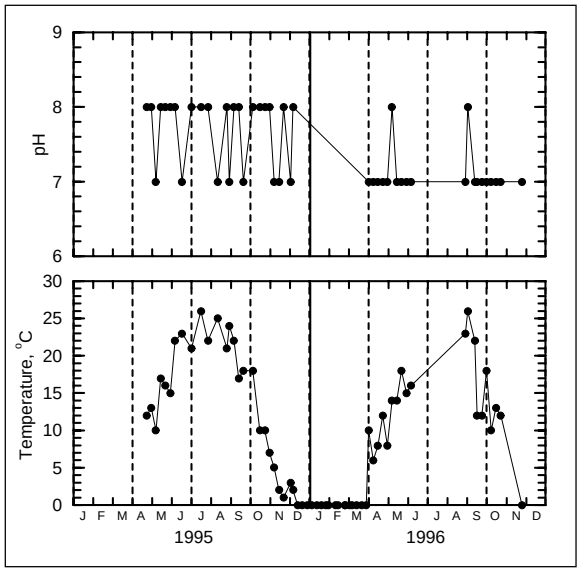
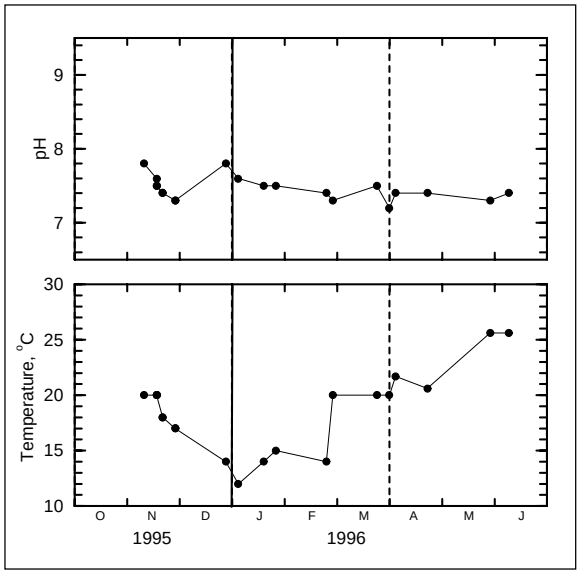


Figure HYD-L-10: GLOBE School in California, USA



Note from the scientists

In the Figure HYD-L-9 we can see that this school is probably making pH measurements using pH paper. This explains the high number of jumps of 1 unit in pH with time. It is entirely possible that the actual pH of the water source being measured by this school in the Midwestern United States is somewhere between pH 7 and pH 8. We would expect slight changes in water pH to push the readings back and forth between two values if they are being made with pH paper.

In Figure HYD-L-10, we see an example of a GLOBE school that is using a pH meter to conduct their measurements. The temperature data show a reasonably smooth temperature progression.

Further Investigations

1. Have students recreate the bottom pH graph as if they were using pH paper by taking each point to the nearest whole number and redrawing the graph.
2. Can trends be identified as easily on the old graph as on the new one?